New Millennium Deep Space Two: The Mars Microprobe Project. S. E. Smrekar, E. R. Stofan, S. A. Gavit, and G. E. Powell, Jet Propulsion Laboratory, California Institute of Technology, MS 183-501, 4800 Oak Grove Dr., Pasadena, CA 91109; ssmrekar@cythera.jpl.nasa.gov.

The Mars Microprobe Project (MMP) is the second of the New Millennium Program Deep Space Missions and is designed to enable future space science network missions through flight validation of new technologies. A secondary goal is the collection of meaningful science data. Two micropenetrators will be deployed to carry out surface and subsurface science.

The penetrators are being carried as a piggyback payload on the 1998 Mars Surveyor Lander cruise ring and will be launched in January of 1999. The Microprobe has no active control, attitude determination, or propulsive systems. It is a single stage from separation until landing and will passively orient itself due to its aerodynamic design. The aeroshell shatters at surface impact, at which time the probe separates into an aftbody that remains at the surface and a forebody that penetrates into the subsurface (see Figure 1). Each penetrator has a total mass of up to 3 kg, including the aeroshell. The impact velocity will be ~180m/s. The forebody will experience up to 30,000 g's and penetrate between 0.3 and 2 m, depending on the ice content of the soil. The aftbody deceleration will be up to 80,000g's.

The penetrators arrive in December of 1999. The landing ellipse latitude range is 73-77°S. The longitude will be selected by the Mars Surveyor Project to place the lander on the polar layered deposits in the range of 180-230°W. The two micropenetrators are likely to land within 100 km of the Mars Surveyor Lander, on the polar deposits. The likely arrival date is L_s 256, late southern spring. The nominal mission lasts 2 days. Data may be acquired for up to several weeks, depending on battery power availability. An Announcement of Opportunity for a small Science Team to participate in data validation, initial analysis, and archival will be issued in the summer of 1997.

The primary technologies to be demonstrated on the MMP and their possible future applications are described below.

Non-errosive Single-stage Entry System. The aeroshell will be made of a non-erosive heat shield material, Silicon Impregnated Reusable Ceramic Ablator (SIRCA), which has been developed at Ames Research Center. A small inside structure provides the necessary support for aft and forebody attachment. The 700 g aeroshell system will be designed to shatter upon impact. Using a non-erosive material represents a mass savings of 50% or more over conventional thermal protection system technologies. It also minimizes aerothermal and aerodynamic analyses. Designing a passive re-orientation system simplifies the attachment and deployment strategy with the 1998 Mars Lander Spacecraft.

Telecommunications. The probe telecommunications system will include a programmable transceiver. This development is exciting because of its multimission capability, which can be used for any moderate rate/range relay for both Earth and space applications. The transceiver programmability extends to the data rate (1 kbps to 500 kbps), the modulation format (FSK or PSK), and the receive/transmit frequency (380 to 480 MHz). The microsubsystem represents a 100X reduction in mass over current spacecraft telecommunications subsystems (< 10 gm), and occupies a very small volume (< 8 cm^3).

Ultra-Low-Temperature Lithium Primary Battery. Probably the most challenging aspect of the microprobe design is the requirement to survive the severe Martian thermal environment. The batteries are likely to stay no warmer than -78° C. To survive this extreme temperature, both lithium-thionyl chloride and lithium-carbon monofluoride battery chemistries are being considered. The microprobe primary battery will be designed for a 6 to 14 V range and a 3-year shelf life. The battery will also have to withstand a worst case 80,000 g rigid body shock environment. Low-temperature battery technology is essential for Mars landers and rovers as well as other deep space missions.

Power Microelectronics: Mixed Digital and Analog ASICs. The microprobe power control, regulation, and distribution will be operated via microelectronics that use mixed digital/analog ASICs. Mixed digital/analog ASICs represent an exciting extension of the miniaturization achieved by the digital electronics industry in the last quarter century. This power system will use CMOS technology with very low temperature capabilities. This technology is useful for a suite of applications including any high density sensor, instrument, or assembly.

Advanced Microcontroller. The microprobes will include an 8051-based data acquisition and control system with modest data processing capability. This microcontroller is an 8-bit processor with 64K RAM and 128K EEPROM. The system is designed for both very low power (< 50 mW at 1 MHz, 1 mW sleep mode) and small volume and mass (< 8 cc, 30 to 90 g). The microcontroller system will also include an internal 12-bit 16-channel analog-to-digital converter (ADC). Because this system has multifunctional applications, it will be developed and funded by a consortium of government and industry participants. Potential applications for this microcontroller include any small system or instrument including microprobes, actuators, and health and status monitors.

Flexible Interconnects for System Cabling. The microprobe's high shock and vibration environment presents a challenge for system-level packaging. One packaging approach that will be demonstrated on this mission is flexible interconnects for system-level cabling. Flex is a Kapton based multilayer circuit carrier and interconnect technology. The flex circuits used for the penetrator will include electrical interconnect layers which are formed with a patented anisotropic bonding material made of thermal glue matrix with embedded solder balls. This bonding technique can withstand temperature extremes and can be used to attach surface mount parts using reflow solder. This approach provides unparalleled bending flexibility and oxidation resistance, and is applicable to any micro sensor, assembly, or instrument.

Instruments. The instrument package is designed to demonstrate that valid scientific measurements of both Mars atmospheric conditions and the subsurface soil characteristics can be obtained using micropenetrators. The instrument package includes an experiment to collect a sample of Martian soil and test for the presence of sub-surface water ice, an aft-body mounted pressure sensor to record the surface atmospheric pressure, a pair of temperature sensors to measure the rate of cooling of the soil after impact, a descent accelerometer to measure atmospheric drag on the microprobe, and a high-g (10-20 Kg) accelerometer to measure the deceleration at impact of the microprobe forebody in the soil.

The primary experiment is the subsurface soil sampling/water experiment. A soil sample will be actively collected from the depth at which the forebody comes to rest. After the sample is collected, the chamber is sealed and the sample is heated to release water vapor. The vapor will flow from the sample chamber through a vented analysis chamber. While in the analysis chamber, the vapor is illuminated by a tunable diode laser (TDL) and the transmitted power signal is measured to observe the presence of the water absorption line at 1.37 µm. If power is available, the sample will be incrementally heated to characterize the mineralogy of the soil sample by recording the strength of the absorption peaks up to a maximum temperature of up to 500° C.

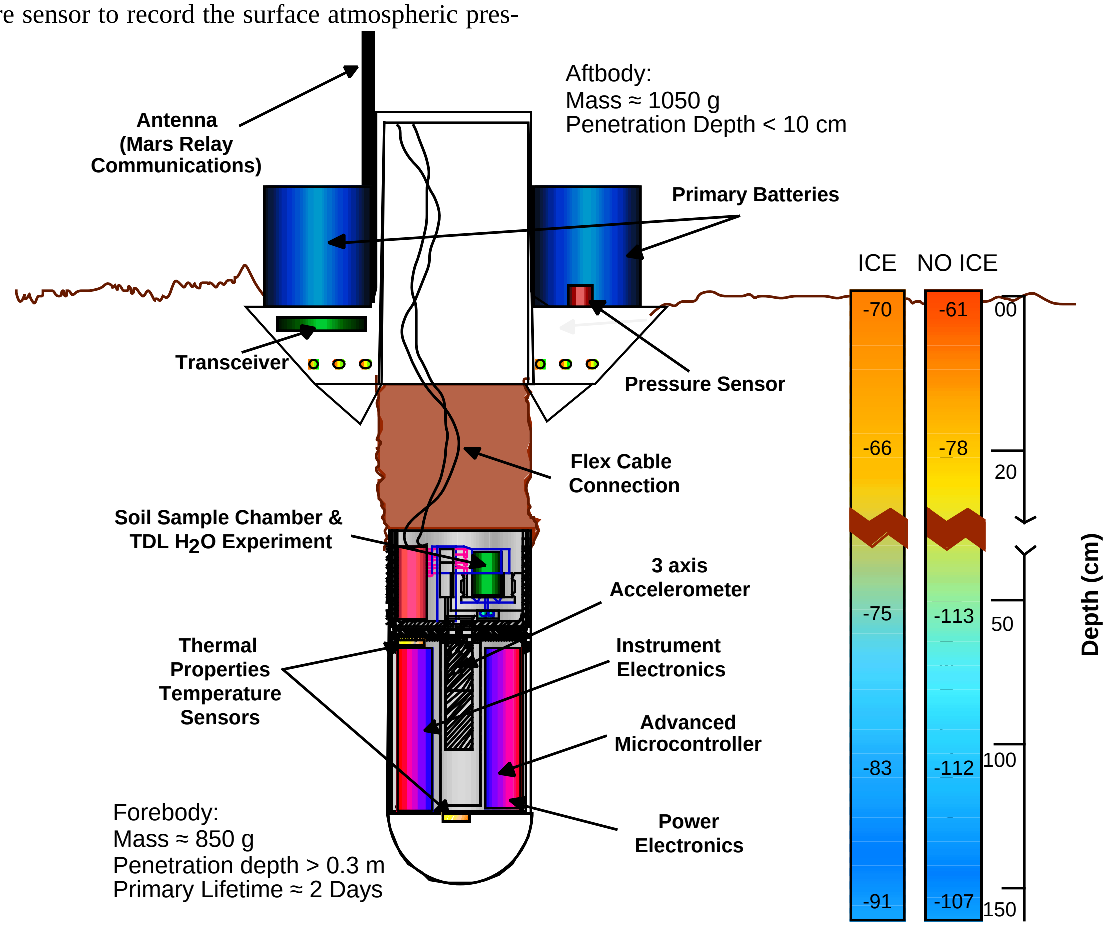

Figure 1. Landed configuration.